The Journal of Cardiovascular Diseases
J Cardiovasc Dis 2025;21(2):83 - 92

ORIGINAL ARTICLE
DOI: 10.55958/jcvd.v21i1.251

OUTCOMES OF CORONARY ARTERY BYPASS SURGERY IN PATIENTS WITH REDUCED LEFT VENTRICULAR FUNCTION AND HIBERNATING MYOCARDIUM

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Date of Submission: 26-07-2025; Date of Acceptance: 10-08-2025; Date of Publication: 10-09-2025

ABSTRACT:

BACKGROUND:

AIMS & OBJECTIVE: *The medium-term functional recovery of the left ventricle (LV) and overall prognosis following coronary artery bypass grafting (CABG) in patients with markedly reduced ventricular function and hibernating myocardium (HM) remains insufficiently defined. This study prospectively investigated postoperative outcomes in patients with severe LV impairment and evidence of myocardial hibernation.*

MATERIAL & METHODS: *A total of 120 consecutive patients with significant LV dysfunction and HM, confirmed through dobutamine stress echocardiography and rest-redistribution thallium-201 imaging, were included. The mean age was 60 ± 9 years (range 31–77), and the mean preoperative ejection fraction (LVEF) was 28 ± 9% (range 25–40%). LV function was evaluated by echocardiography intraoperatively, before discharge, at three months, one year, and annually thereafter. Predictors of survival were analyzed using univariate and multivariate statistical methods.*

RESULTS: *Early mortality was 1.6% (n=2), and 12.5% (n=15) died during late follow-up, predominantly from heart failure. Actuarial survival was 80 ± 6% at five years and 60 ± 9% at eight years. LVEF improved significantly following surgery (from 28 ± 9% to 40 ± 2%, $p < 0.01$), although this early gain progressively diminished over time, with mean LVEF decreasing to 33 ± 9% at three months, 32 ± 8% at one year, and 30 ± 9% at eight years. Patients who showed minimal early recovery of LV function experienced a more rapid decline in EF and more frequent recurrence of heart failure. Freedom from heart failure was 82 ± 5% at four years and 60 ± 8% at eight years. Advanced preoperative NYHA class and older age independently predicted poorer long-term survival, whereas preoperative angina and use of arterial grafts did not significantly affect long-term outcomes.*

CONCLUSION: *CABG in patients with hibernating myocardium and severely depressed LV function results in meaningful early improvement in ventricular performance and generally favorable overall prognosis. However, the functional benefit tends to diminish over time. Older age, advanced heart failure at presentation, and limited perioperative improvement in LVEF are associated with less favorable long-term outcomes.*

KEY WORDS: *Coronary artery bypass grafting; Hibernating myocardium; Left ventricular dysfunction; Ischemic cardiomyopathy; Postoperative outcomes; Long-term survival; Ventricular function recovery*

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INTRODUCTION:

Surgical revascularization has been shown to offer a long-term survival advantage over medical therapy alone in patients with marked left ventricular (LV) dysfunction[1,2]. Although improvement in myocardial performance following coronary artery bypass grafting (CABG) has been demonstrated, reduced LV contractility continues to be an important predictor of poorer postoperative outcomes[1]. In recent years, particular attention has been directed toward the concept of hibernating myocardium (HM)—regions of akinetic but viable myocardium that may recover function after restoring coronary blood flow [2]. Patients exhibiting HM appear to have a greater likelihood of functional LV recovery and improved survival following revascularization [2].

The ability to identify reversible myocardial dysfunction has therefore become highly relevant, leading to the development and use of several diagnostic modalities aimed at detecting HM and guiding therapeutic decision-making. Clinical presentation prior to surgery also influences prognosis. For example, patients presenting with angina often demonstrate better long-term outcomes compared with those experiencing heart failure symptoms, likely reflecting the presence of viable myocardium capable of functional recovery[3].

Despite extensive discussion regarding the prognostic impact of LV dysfunction and the importance of appropriate patient selection, limited data are available on long-term outcomes after CABG specifically in patients who have both significant LV impairment and documented HM. The durability of surgical benefit and the factors that predict adverse late outcomes in this subgroup remain uncertain. To address this gap, we prospectively studied a cohort of patients with severe LV dysfunction and evidence of HM, and we present the findings of their long-term follow-up.

MATERIAL AND METHODS:

This retrospective study enrolled 120 consecutive patients who underwent coronary artery bypass grafting (CABG) between February 2018 and April 2025. Patients were included if they had severe left ventricular systolic dysfunction, defined as an ejection fraction of 40% or less confirmed by echocardiography and left ventriculography, and demonstrated substantial segments of hibernating myocardium. Additional inclusion criteria required the presence of graft-able coronary anatomy, elective surgical status, and the absence of acute myocardial infarction within the preceding month. Baseline demographic and clinical information was collected for all participants [Table-1].

Preoperative assessment of myocardial viability followed a standardized protocol. All patients first underwent transthoracic and subsequently transesophageal echocardiography to identify akinetic yet potentially viable myocardial regions. Dobutamine stress echocardiography was then performed according to established infusion protocols to determine contractile reserve. To further differentiate viable myocardium from irreversibly infarcted tissue, rest–redistribution Thallium-201 scintigraphy was carried out in every case. Coronary angiography was used to define the extent of coronary artery disease, vessel caliber, and overall suitability for bypass grafting; vessels demonstrating ≥70% stenosis was considered for revascularization.

Cardioplegia methods varied according to institutional practice during different periods. St. Thomas hospital blood cardioplegia was used in early years, later after 2023 all patients received Del-Nido blood cardioplegia. Earlier in the study, most patients were revascularized exclusively with saphenous vein grafts, whereas in the later years the left internal thoracic artery was routinely used to bypass the left anterior descending artery. The majority of patients underwent complete revascularization, with an average of nearly three grafts implanted per patient. Additional surgical procedures were performed when needed, including mitral valve repair in three patients with significant regurgitation and aortic valve replacement in one patient with concomitant valvular disease.

Intraoperative assessment of ventricular function was conducted

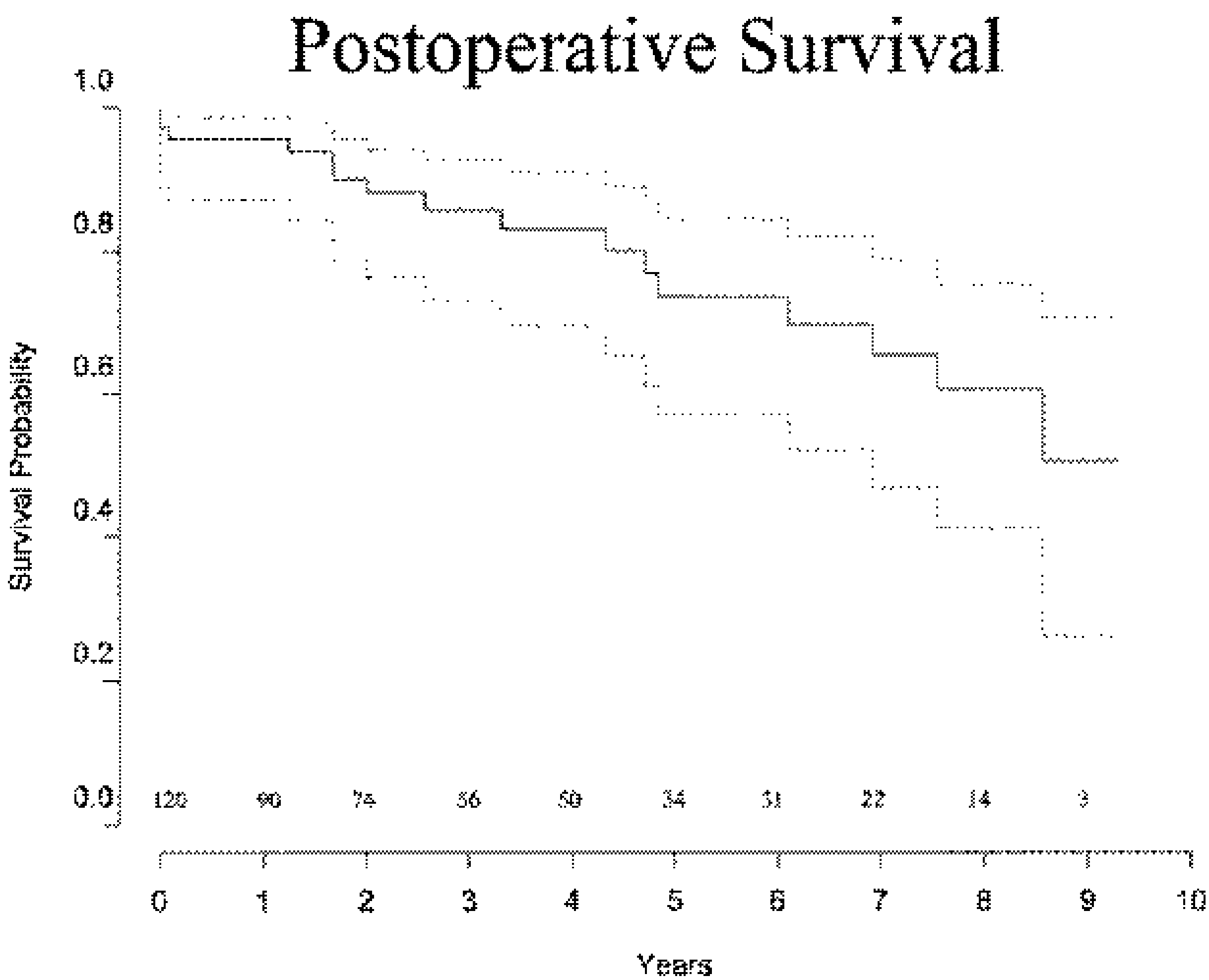

Figure 1. Kaplan–Meier overall survival curve after CABG showing survival to 8 years.

using transesophageal and epicardial echocardiography. Postoperatively, all patients were evaluated with transthoracic echocardiography prior to hospital discharge, at three months, at twelve months, and annually thereafter. A subset of patients underwent postoperative coronary angiography or nuclear imaging within the first postoperative year, although those results were considered preliminary. All patients received guideline-directed medical therapy including ACE inhibitors, diuretics, and, beta-blockers; however, there was no uniform protocol for lipid-lowering or antiarrhythmic therapy.

Continuous variables are presented as mean ± standard deviation. Changes in left ventricular ejection fraction over time were assessed using linear mixed-effects models for repeated measures. Predictors of survival were analyzed first with univariate testing, followed by multivariate Cox proportional hazards modeling. Variables examined in the analysis included age, gender, history and anatomical location of prior myocardial infarction, presenting symptoms, use of arterial grafts, baseline ejection fraction, pulmonary hypertension, diabetes mellitus, New York Heart Association (NYHA) class, number of distal anastomoses, cardiopulmonary bypass duration, aortic cross-clamp time, type and route of cardioplegia, and the degree of perioperative improvement in ejection fraction. A p-value of less than 0.05 was considered statistically significant.

RESULTS:

A total of 120 patients were followed for a mean duration of 3.8 ± 1.6 years (range: 3 months to 8 years), and no patient was lost to follow-up. There were two in-hospital deaths (1.6%) and fifteen late deaths (12.5%). The majority of late deaths were attributed to progressive

Table 1. Baseline Clinical and Preoperative Characteristics of the Study Population (n = 120).

Variable	Value
Age (years)	58 ± 8
Male sex	92 (76.7%)
Diabetes mellitus	41 (34.2%)
Hypertension	48 (40.0%)
Smoking history	67 (55.8%)
Hyperlipidemia	36 (30.0%)
NYHA Class III–IV	74 (61.7%)
Previous myocardial infarction	63 (52.5%)
LVEF (%)	28 ± 9
Documented hibernating myocardium	120 (100%)
Triple-vessel disease	101 (84.2%)
Left main disease	18 (15.0%)
Viability confirmed by DSE	107 (89.2%)
Viability confirmed by Thallium-201	98 (81.7%)

Table 2. Causes of Early (≤30 Days) and Late (>30 Days) Mortality After CABG.

Cause of Death	Early Deaths (n = 2)	Late Deaths (n = 15)
Congestive heart failure	1	7
Myocardial infarction	0	3
Sudden cardiac death	0	3
Non-cardiac causes (e.g., renal failure, stroke, malignancy)	1	2
Other postoperative complications	0	0

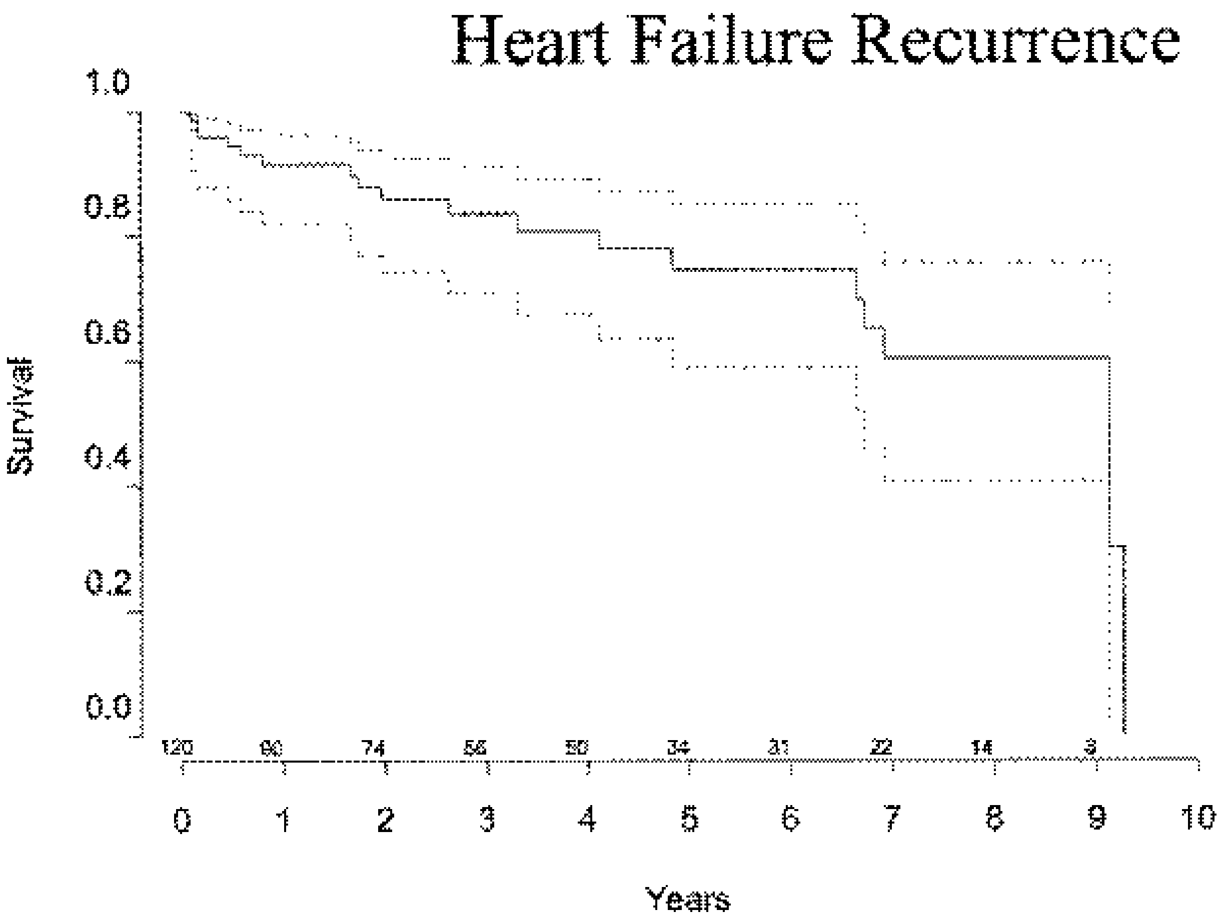

Figure 2. Freedom from heart failure recurrence over long-term follow-up.

Table 3. Multivariate Cox Regression Analysis for Predictors of Long-Term Mortality.			
Variable	**Hazard Ratio (HR)**	**95% CI**	**p-value**
Age (per year increase)	1.04	1.01–1.08	0.02
NYHA Class III–IV	1.67	1.15–2.74	0.01
Diabetes mellitus	1.21	0.83–1.89	0.27
LVEF (per 5% decrease)	1.12	0.95–1.30	0.11
Use of LITA graft	0.89	0.63–1.27	0.48
Presence of angina	1.03	0.70–1.51	0.89

heart failure, while a smaller number resulted from myocardial infarction, sudden cardiac death, or non-cardiac causes. The distribution of perioperative and late mortality is summarized in Table 2, which demonstrates that chronic heart failure constituted the predominant cause of late death.

Kaplan–Meier survival analysis revealed an actuarial survival of 84 ± 6% at four years and 60 ± 9% at eight years after CABG. The survival curve, illustrated in Figure 1, shows a gradual decline in long-term survival largely influenced by the severity of preoperative ventricular dysfunction. Notably, sudden cardiac death was infrequent, with only three such events occurring during follow-up.

Left ventricular ejection fraction (LVEF) improved significantly in the immediate postoperative period, rising from a preoperative mean of 28 ± 9% to 40 ± 2%

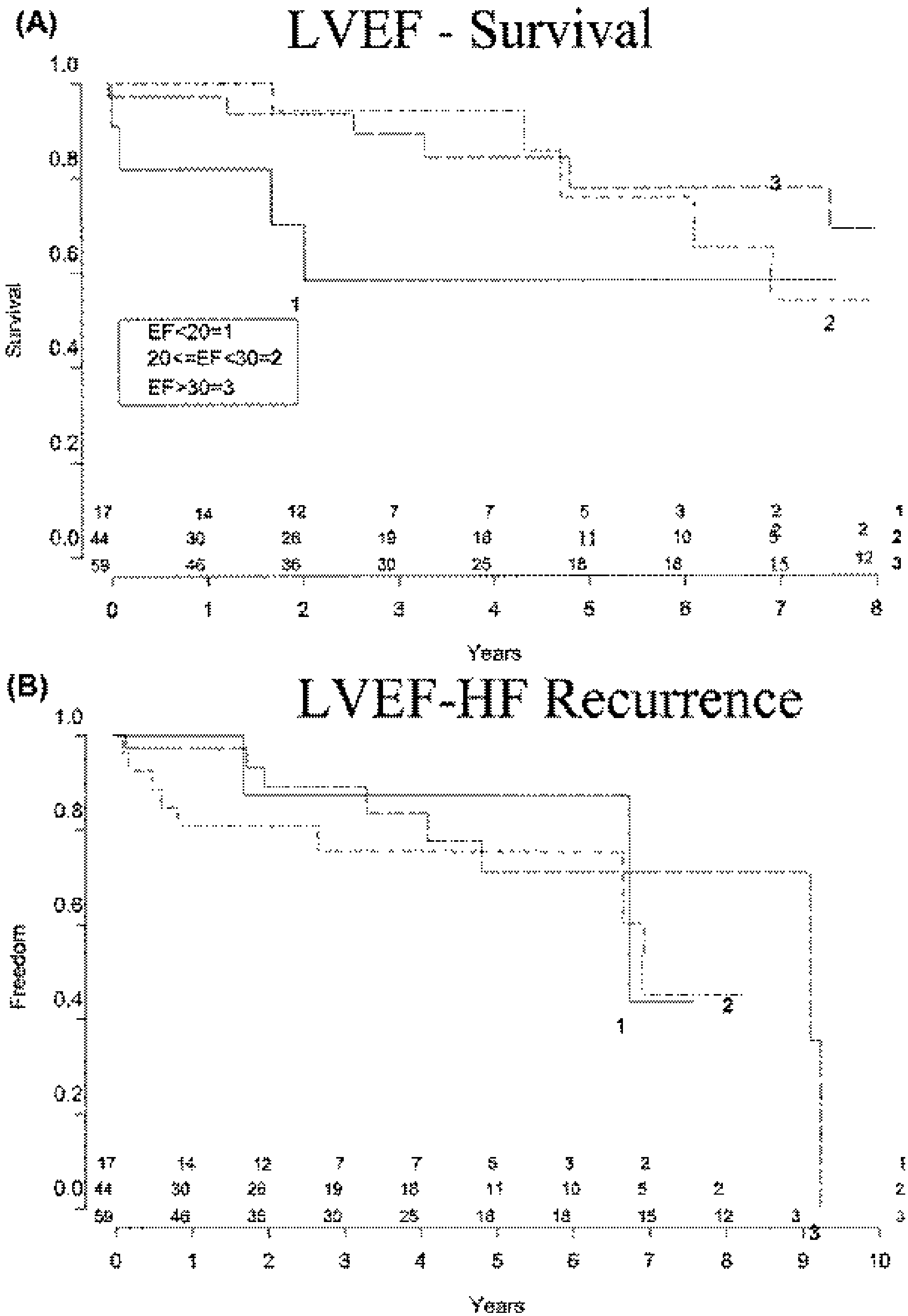

Figure 3. (A) Survival by preoperative LVEF; (B) Heart failure recurrence by LVEF.

($p < 0.01$). However, this improvement was not fully sustained over time. As depicted in Figure 3, LVEF declined gradually to 33 ± 9% at three months, 32 ± 8% at one year, and 30 ± 9% at eight years. Patients who demonstrated a limited perioperative increase in LVEF were more likely to experience subsequent deterioration in ventricular function.

Heart failure recurrence mirrored this pattern. The freedom from heart-failure–related readmission was 82 ± 5% at four years and 60 ± 8% at eight years, as shown in Figure 2. Patients with advanced preoperative NYHA class were particularly prone to late recurrence. Although the early postoperative period was characterized by an improvement in symptoms, late decline in functional status was observed, with 35% of patients reverting to NYHA class III or IV symptoms at eight years.

The influence of preoperative LVEF on postoperative trajectory was evident. As illustrated in Figure 3A, patients with more profound systolic dysfunction exhibited lower survival, while Figure 3B demonstrates that heart failure recurrence was more common in this subgroup. Similarly, patients with minimal perioperative recovery experienced higher readmission rates and worse long-term hemodynamic outcomes.

The type of conduit used for LAD revascularization did not significantly affect survival or freedom from heart failure. Figure 4 compares outcomes between patients receiving left internal thoracic artery (LITA) grafts and those receiving saphenous vein grafts; no statistically significant differences were observed during the follow-up period. Furthermore, only three patients required percutaneous intervention during follow-up, and no patient required redo CABG.

Univariate analysis identified extracorporeal circulation time, aortic cross-clamp duration, advanced NYHA functional class, and age as predictors of reduced survival. Multivariate Cox regression confirmed that only age and preoperative NYHA class remained independent predictors of mortality. These results are summarized in Table 3. The presence of preoperative angina did not confer a survival advantage, nor did it reduce the incidence of postoperative heart failure.

Rhythm disturbances occurred infrequently in this cohort. Only one patient required postoperative implantation of an automated implantable cardioverter-defibrillator due to documented ventricular tachycardia. Most patients were maintained on standard heart-failure–directed therapy at follow-up, with 40% continuing baseline treatment and 30% requiring escalation of medical therapy.

DISCUSSION:

In this study, we evaluated long-term outcomes of coronary artery bypass grafting in patients with markedly reduced left ventricular systolic function who also demonstrated substantial hibernating myocardium. Our findings confirm that CABG in this high-risk population provides an acceptable early mortality rate and a meaningful improvement in ventricular function, although long-term functional benefit appears to be limited for many patients. These results reinforce the significance of myocardial viability in surgical decision-making while highlighting the complexity of managing ischemic cardiomyopathy [4,10,11].

The early postoperative improvement in LVEF observed in our cohort supports prior evidence that revascularizing viable but dysfunctional myocardium results in prompt recovery of contractile function. Immediate postoperative echocardiography showed a significant rise in LVEF, consistent with the physiological concept that hibernating myocardium regains function once adequate perfusion is restored [5,14]. However, the subsequent gradual decline in LVEF over the follow-up period suggests that early gains in mechanical performance may not be durable in all patients. The trend noted indicates that although CABG effectively restores myocardial perfusion, the underlying myopathic process likely progresses over time, particularly in patients with extensive preoperative ventricular remodeling [6,7].

The recurrence of heart failure symptoms, reported in Figure 2, further underscores this phenomenon. Even though symptomatic benefit was substantial during the first few postoperative years, late decline in functional status was common. Patients with severe symptoms preoperatively (NYHA III–IV) experienced the poorest outcomes, as confirmed by multivariate analysis. This suggests that advanced functional impairment reflects a greater degree of irreversible myocyte loss and fibrosis, limiting the extent and durability of postoperative recovery[14]. These observations are in line with previous work demonstrating that structural abnormalities—rather than viability alone—determine long-term recovery potential.

An important observation in our study is the low incidence of sudden cardiac death despite the well-known association between ischemic cardiomyopathy and malignant ventricular arrhythmias. Only three such events occurred during follow-up. This contrasts with earlier reports in which arrhythmic deaths accounted for a large proportion of mortality in similar populations [5,8]. One possible explanation is that restoring flow to hibernating myocardial segments stabilizes the electrophysiological substrate, thereby reducing ventricular irritability. While our study design does not allow a mechanistic explanation, the low rate of late arrhythmic events suggests that revascularization may have a protective effect against sudden death in carefully selected patients [1-3,9].

The type of conduit used for LAD grafting did not influence long-term survival or heart failure recurrence. As shown in Figure 4, outcomes were comparable between patients receiving internal thoracic artery grafts and those receiving venous conduits [10]. Although arterial grafts are generally associated with superior long-term patency, their survival advantage may be attenuated in patients with extensive ventricular dysfunction, where the limiting factor is less often grafting failure and more often the progression of intrinsic myocardial disease. Furthermore, our follow-up period, although substantial, may not have been long enough to detect differences associated with late conduit attrition.

Predictors of survival identified in Table 3 emphasize the central importance of preoperative clinical status. Advanced NYHA class and older age independently predicted poorer long-term outcomes. Conversely, preoperative angina did not confer a protective effect, a finding that differs from some reports suggesting that angina may reflect the presence of viable myocardium[7]. In our study, all patients had documented viability, which may explain why angina did not distinguish clinical subgroups. These findings highlight that viability alone does not guarantee sustained benefit after revascularization if overall ventricular reserve and clinical stability are severely compromised.

Although CABG clearly provides early symptomatic and functional improvement in patients with hibernating myocardium, the long-term outcomes in our study reveal important limitations. The gradual reduction in LVEF, the recurrence of heart failure, and the influence of preoperative clinical severity all point toward the multifactorial nature of ischemic cardiomyopathy[11]. Factors such as progression of diffuse coronary disease, graft occlusion, incomplete revascularization, and ongoing myocyte degeneration may contribute to the eventual decline. Therefore, long-term management of these patients must involve not only surgical revascularization but also aggressive optimization of medical therapy, close functional surveillance, and timely follow-up imaging to detect potentially reversible causes of deterioration.

This study also underscores the need for improved strategies for assessing myocardial structure in addition to viability. Conventional viability tests such as dobutamine stress echocardiography and Thallium-201 scintigraphy are valuable for identifying hibernating myocardium, but they may not fully reveal the degree of structural fibrosis or myocyte integrity. Future incorporation of advanced imaging modalities—such as cardiac MRI with late gadolinium enhancement or PET-based metabolic profiling—may enhance preoperative risk stratification and improve the selection of patients most likely to benefit from revascularization [12,13].

CABG in patients with reduced LVEF and hibernating myocardium provides low operative mortality, early improvement in ventricular function, and acceptable long-term survival. However, the long-term trajectory of ventricular performance is characterized by gradual decline, particularly in patients with severe preoperative symptoms or limited perioperative improvement. Our findings highlight the importance of comprehensive preoperative assessment, individualized postoperative care, and long-term surveillance to optimize outcomes in this challenging population.

CONCLUSION:

In patients with markedly reduced left ventricular function and demonstrable hibernating myocardium, coronary artery bypass grafting offers a meaningful survival advantage and an early improvement in ventricular performance. Although perioperative recovery of left ventricular ejection fraction is substantial, this benefit is not consistently sustained over long-term follow-up, particularly in individuals with advanced preoperative heart failure or minimal perioperative functional improvement. The recurrence of heart failure symptoms and the progressive decline in ventricular function observed during follow-up emphasize the complex, multifactorial nature of ischemic cardiomyopathy. Nevertheless, operative mortality remains low, and the risk of sudden cardiac death is markedly reduced, underscoring the value of revascularization in appropriately selected patients. Future management should incorporate refined imaging strategies to better characterize myocardial structural integrity and guide patient selection. Comprehensive long-term clinical follow-up and optimized medical therapy remain essential components of care to maximize the benefits of surgical revascularization in this high-risk population.

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